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STRUCTURE AND EVOLUTION OF THE UNIVERSE SUBCOMMITTEE

OF THE
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December 3–4, 2002

NASA Headquarters
Washington, DC

MEETING REPORT

Paul Hertz	**Edward W. Kolb**
Executive Secretary	**Chair**

STRUCTURE AND EVOLUTION OF THE UNIVERSE SUBCOMMITTEE (SEUS)

December 3–4, 2002
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Tuesday, December 3

Welcome and Agenda
Dr. Edward "Rocky" Kolb, Chair of the Structure and Evolution of the Universe Subcommittee (SEUS), welcomed those present and asked for brief introductions. Dr. Paul Hertz, SEUS Executive Secretary, reviewed the agenda. Most of Tuesday was scheduled for a joint session with the Origins Subcommittee (OS). Major topics for the remainder of the SEUS meeting were to include discussion with the Office of Science and Technology Policy (OSTP) on how federal agencies could work together in response to the National Research Council, Board on Physics and Astronomy, report, *From Quarks to the Cosmos*; plans for dissemination of the Structure and Evolution of the Universe (SEU) roadmap, *Beyond Einstein*; the joint National Science Foundation (NSF)/NASA balloon program; and plans for an Ultra-Long Duration Balloon (ULDB) program. In his opening comments, Dr. Hertz also updated the members on the approval status of the charter for SEUS as a federal advisory committee. The Chair adjourned the meeting at 9:00 a.m. to join the OS meeting in progress.

Joint Meeting with Origins Subcommittee

[Insert minutes from joint SEUS/OS session]

Discussion with OSTP
The SEUS resumed its own meeting at 2:55 p.m., after an unanticipated delay for a fire drill.

Dr. Patrick Looney, Assistant Director for Physical Sciences, OSTP, discussed OSTP's view of *From Quarks to the Cosmos*, also known as the Turner Committee report. His review of the many reports from federal advisory committees, as well as the National Research Council reports, found more recommendations for physical sciences research than could be undertaken even in the best of funding environments. On the positive side, a recent report from the President's Council on Science and Technology advocated an increased investment in physical sciences research. His difficulty is prioritizing the recommendations from multiple reports, particularly since the top priorities in each report are all good science. The emphasis in *From Quarks to the Cosmos* on interagency cooperation and coordination has struck a chord with the Office of Management and Budget (OMB), as well as with OSTP and other offices in the Executive Branch. In Dr. Looney's view, the *Beyond Einstein* roadmap that SEUS developed gives NASA a head start, as it represents an appropriate and already formulated response to the challenges voiced by the Turner Committee. The Gamma-ray Large Area Space Telescope (GLAST) exemplifies the type of experiment Dr. Looney sees as responding to the challenge. OSTP will be trying to formalize a process for recognizing opportunities, and priorities may need to be set across multiple agencies. Coordination of activities implies coordination of funding streams. NASA's Laser Interferometer Space Antenna (LISA) and NSF's Laser Interferometer Gravity Observatory (LIGO) are complementary, so Dr. Looney believes there should be coordination across them. In response to a question, he expressed interest in a mechanism for competition across agencies on similar projects.

Dr. Looney and SEUS members exchanged views on how to proceed with dissemination and implementation of the *Beyond Einstein* roadmap. He noted that, although homeland security and national security are clearly the Administration's top priorities, it is also supportive of basic research priorities. Although large new starts (measured in billions of dollars) are unlikely, he sees possibilities for expanded support of basic research in physical science, now that the Administration has completed the commitment to double the National Institutes of Health budget. He expects OSTP to take an active role in working out coordination across agency research programs. Both OMB and OSTP are watching how the National Astronomy and Astrphysics Advisory Committee (NAAAC) works, as well as following the work of SEUS and other NASA advisory committees. The National Science and Technology Council is another potential means for responding to the challenges presented in National Research Council reports. In closing, Dr.

Looney expressed interest in further exposition of the relation between theory and modeling discussed in Chapter 4 of *Beyond Einstein*, particularly with regard to computing as a tool for discovery.

NSF/NASA Polar Programs

Dr. W. Vernon Jones of NASA described the joint NSF/NASA Polar Program, with an emphasis on the status and future prospects of the balloon program. A long duration balloon (LDB) flight is more than 10 days. An ultra-long duration flight is more than 100 days. The program has had one flight in Antarctica of 32 days, two Arctic flights of 13 day s each. For Arctic flights, international agreements to allow overflight and recovery are essential but politically sensitive. LDB flights can have 2,700 kg payloads; they use the same balloons as 1-2 day conventional flights. The difference is that LDB uses more sophisticated control and support instrumentation, such as Global Positioning System (GPS) tracking and satellite communications (e.g.. the Tracking and Data Relay Satellite System [TDRSS]). On Antarctic LDB flights, the trajectories have been more or less circular. There is little deviation in altitude because the balloon temperature remains fairly constant when the flight trajectory is near or above (in latitude) the Antarctic Circle. Superpressure ballooning, which is the key to ULDB, uses constant volume balloons, not constant pressure. The basic balloon technology is established; a major technical issue is trajectory control to keep the balloon away from large cities. Superpressure ballooning started with a 1993 flight from New Zealand to a circular trajectory around Antarctica. The payload was small, just 130 lb., but this success led to the current proposal for a ULDB program. The steady circumpolar winds south of the Antarctic Circle make a 100-day demonstration ULDB flight from New Zealand feasible, as shown by computer simulation results that Dr. Jones shared with the SEUS. Without trajectory control, however, ULDB flights are not feasible over the Arctic (a multi-orbit trajectory there is too unstable). The third option of flying at lower latitudes in the Southern Hemisphere requires trajectory control to avoid no-flight zones over African and South American cities. (Planned recovery in this option would be over Australia.) Trajectory control technology for either of the non-Antarctic flight options is still in the prototyping phase and will require $1 million to $1.5 million to achieve operational status.

Since the NSF/NASA joint program began with a Memorandum of Understanding (MOU) in August 1988, there have been roughly 2 flights per year. Dr. Jones sees this flight rate as what was anticipated from the beginning. Dr. Peacock views it as more than the one flight every other year that NSF anticipated. As one metric for the scientific value of the program, 9 percent of all space science articles in *Science News* have come from the balloon experiments. The viable options for resources to launch an Antarctic ULDB demonstration flight after 2005 require eliminating balloon flights in fiscal year (FY) 2004 and 2005. Substantial additional funding is required even for an LDB Antarctic campaign in FY 2004. NSF is seeking a new MOU in which NASA would provide the resources needed to replace, refurbish, and relocate infrastructure for the program. Until now, NSF has provided the infrastructure under the 1988 MOU. NSF has expressed interest in participating in a NASA-funded workshop in Spring 2003 to define science goals for the LDB program and justify the infrastructure upgrade. NSF's latest estimate (prepared for the SEUS meeting) of infrastructure upgrade requirements is $2 million to $5 million. The shortfall in FY 2003 funding, if uncovered, would mean no balloon flights in 2004.

Dr. Dennis Peacock, science director of the U.S. Antarctic Program, presented the NSF perspective on the joint Polar Programs. As the statutory lead agency for the U.S. Antarctic Program, NSF is responsible for managing and budgeting. Science programs within the U.S. Antarctic Program are often funded by agencies other than NSF, such as NASA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey. In the past, the program was heavily funded by the Department of Defense, particularly the Navy. The NSF Office of Polar Programs, which organizationally is between being a NSF directorate and a division, now reports to the NSF Director's Office. The U.S Antarctic Program maintains three stations in Antarctica. McMurdo Station, near the LDB facilities, is on the edge of the Ross Ice Shelf. The Crary Science and Engineering Center at McMurdo Station has 40,000 square feet of interior space, mostly for biological research. At the South Pole Station, a modernization project will provide additional ground-based astronomy and astrophysics experiments. The NSF commitment to the Ice Cube Project at the South Pole Station is for $240 million. Dr. Peacock stressed the need to balance the interests and requirements of the range of work under the Polar Programs. For example, NSF funds most of the Antarctic Search for Meteorites, while NASA provides funds for the analysis. A major issue for the renegotiation of the NSF-NASA MOU is funding for the infrastructure to support the balloon program. Each year an airfield is created on the sea ice at the same location, but this location is moving closer to the ice shelf edge. NSF is asking NASA to help pay for the relocation of the airfield, estimated at $2 million to $3 million. Another $600,000 to $800,000 is needed just for temporary fixes to the old infrastructure, to enable the next two launches. A balloon assembly building is needed, plus 1,000 ft. of flat space to set up the balloon. The operational costs for two balloon flights per year are approximately $1million per year.

The SEUS members discussed various options with the speakers, such as launching the ULDB demonstration from Christchurch, New Zealand, or waiting for trajectory control to be operational. The position of the balloon program among other NSF priorities was discussed, including whether a workshop on balloon program science goals would affect existing priorities for infrastructure. The impact of the FY 2003 budget shortfall on the FY 2004 flight schedule was discussed, but no clear solutions emerged. All the technical options developed by the speakers for dealing with the flight schedule for the next several years require a combination of Arctic and Antarctic flights.

Next Steps For *Beyond Einstein*

The SEUS discussed next steps in disseminating and building support for the *Beyond Einstein* roadmap. The final version has been sent to the printer. A booth is being designed for the American Astronomical Society (AAS) meeting in January 2003. The booth will also go to the next IEEE conference, as well as to other scientific meeting venues. The possibility of a seminar on the roadmap for science writers attending the AAS meeting was discussed. A compact disk (CD) containing presentations designed for teachers at different grade levels was discussed. Dr. Lynn Cominsky described some of the plans she has developed for educational materials related to post-Einstein physics topics, such as black holes. Members were asked to email materials for the CD, such as animations, to Dr. Hertz. A poster (for conference poster sessions) will be prepared. There will be an eight-page brochure, based on the general chapter of the roadmap but written to communicate to a general audience. A CD oriented to a scientific audience was discussed. The Chair suggested that articles about the roadmap could be prepared for submission to general science magazines such as *Sky and Telescope*, *Scientific American*, *Astronomy*, and perhaps *Nature*. Colloquia with congressional leaders and key staffers, involving leading scientists, are being considered. Lecture series such as the Smithsonian series at the Museum of Natural History and the Carnegie Institution Colloquia were noted as dissemination possibilities.

For the longer term, a joint NASA-DOE meeting is being discussed for 2005, to celebrate Einstein's 1905 paper [on the electrodynamics of moving bodies, which introduced special relativity]. NSF may be asked to participate.

Wednesday, December 4

The meeting agenda for the second day was reorganized. The update on the Explorer Program was moved to the first item on the day's agenda, followed by the presentations on ULDB Science Topics and the ULDB Program. The update briefing on the Research and Analysis (R&A) Program was rescheduled as a mailout to be distributed to the members after the meeting. Dr. Hertz distributed to the SEUS members the briefing materials on the R&A Program that had been prepared by Dr. Michael Salamon.

Explorer Program

Dr. Paul Hertz began the update on the Explorer Program with a review of the letter sent from the SEUS after its previous meeting to Astronomy and Physics (A&P) Division Director Anne Kinney. In the letter, the SEUS suggested that the Office of Space Science solicit feedback from principal investigators (PIs) who submitted proposals to the Explorer Announcement of Opportunity (AO) to determine if the existing mission cost caps were appropriate. Emails soliciting PI comments on any part of the process were sent to the PIs of the 42 Medium-class Explorer (MIDEX) proposals. The email specifically asked about requirements and constraints on proposals in the AO, poorly articulated policies, confusing instructions, hidden requirements, and the evaluation and selection process. Eight responses were received from the 42 proposing teams, with 2 responses received from members of the same team. One of the five selected teams responded; the other seven teams had not been selected. Four responses cited the quality of the technical management and cost (TMC) review as a problem. The quality of the feedback from reviewers, the length of the process (too long), and the selection process were each cited by two responding teams as problems.

One team cited the quality of the science peer review as a problem, and one thought that missions of opportunity were at a disadvantage.

Dr. Hertz described the specific problems mentioned and the respondents' suggestions for improvement. With respect to the suggestion that the final debrief be a written evaluation, Dr. Hertz noted that written evaluations might be subject to Freedom of Information Act (FOIA) requests, so the debriefings are oral. On the other respondent suggestions, he indicated whether there were implementation issues and what approaches to implementing each suggestion might be feasible. The SEUS discussed various ways to improve the debriefing process while preserving the confidentiality of the evaluation. With respect to consistency of reviewer evaluation and comment from one AO to the next (corporate memory in the review process), Dr. Hertz said that consistency in the scientific peer reviews was not a concern, as different groups of reviewers may evaluate proposals differently. However, the TMC reviews should be consistent. The SEUS discussed options for a preproposal process, including the benefits and disadvantages for proposers.

With respect to the SEUS concerns about the current mission cost caps, OSS is raising the Small Explorer (SMEX) cap from $100 million to $120 million. The increase responds to the concerns expressed by the SEUS and other groups. Since the total SMEX program budget remains at the legislated amount, an increase in average SMEX mission cost will require a corresponding decrease in the number of SMEX missions. The mission of opportunity cap is unchanged. The SMEX AO will be released in February 2003, with proposals due 90 days later. With respect to the SEUS concern about availability of small launch vehicles, OSS has established a Headquarters task force to determine when launch vehicle availability will become an issue and the options for addressing it. The report of the task force is due in 6 to 12 months. Code S and Code M will evaluate the options developed. The SEUS discussed the impact of the SMEX cost cap increase on mission launch rate, including the payload advantages of Taurus vehicles relative to the Pegasus vehicle. The MIDEX cost cap is likely to be increased to keep it approximately twice the SMEX cap, which would place it in the $200-$240 million range.

ULDB Science Topics

Dr. Simon Swordy briefed the SEUS on science topics for which a ULDB program is well suited. The topics relevant to the SEU program fall generally under the headings of gamma-ray astronomy, cosmic ray measurements, and neutrino detection. He began with the electromagnetic (EM) range over which balloons at medium or high altitude are effective as observing platforms. For gamma-ray astronomy, a precursor to the Advanced Compton Telescope and other prototype telescopes could be flown on a ULDB. A low-energy gamma-ray Compton telescope would observe photons with energies around 1 Mev. One limitation in using a balloon to fly a telescope in this category is interference from atmospheric gamma rays. Dr. Swordy described a telescope concept from Dr. Steven Boggs at University of California, Berkeley, in which germanium detectors are used to detect the Compton interactions. The objective would be to look at galactic nuclear line radiation. The technique may also be useful for polarization measurements on gamma rays in the range of hundreds of kilo-electron volts to 1 Mev.

In the area of cosmic ray measurements, the objective is to look for rarer particles, including high energy nuclei, electrons, nuclei heavier than iron, and antiparticles. Detector sizes measured in square meters would be appropriate, which fits with ULDB capabilities. One limitation with a balloon-borne experiment is the residual atmosphere, which corresponds to about 5 g/cm^2 of nitrogen. This is equivalent to about 10 percent of the nitrogen a gamma ray encounters in traversing the galaxy. The impact of this atmospheric exposure of this depends on the particles for which one is looking. Science questions that could be addressed include the average spectral index of cosmic ray sources, particularly for higher-energy sources (up to 1 to 10 Tev), and explanations for the knee in the cosmic ray spectrum. Measurements of ultraheavy nucleons can shed light on the source material of cosmic radiation. Dr. Swordy discussed the range of exposure times (related to balloon flight duration) needed to perform some of the cosmic ray measurements of interest. The Cosmic Ray Energetics and Mass (CREAM) experiment, which is scheduled to fly on a balloon, uses redundant energy measurements by different but complementary techniques (transition radiation detectors and calorimetry) to improve the reliability and resolution of particle energy measurements. Dr. Swordy used this project to illustrate the value of the balloon program for involving undergraduate and graduate students in space science experiments. Dr. Steve Meyer provided Dr. Swordy with notes on how a ULDB program could contribute to cosmic microwave background anisotropy studies. The sensitivity of these studies is limited by the integration time, and the integration time on a ULDB flight could be ten times that of a typical LDB flight. Background interference is reduced by a factor of 4 at balloon altitudes, compared with ground-based observation. There are additional reasons why ULDB experiments would be preferable to ground-based observations. In response to a question, Dr. Swordy compared the observational capabilities of ground-based, within-atmosphere (e.g., balloon-based), and space-based telescopes. Balloons offer capabilities that lie between those provided by ground-based and space-based telescopes. ULDB telescopes could, for instance, be used to look at polarization in the cosmic background microwave radiation. This led to a discussion of relative merits and constraints for ground-based versus balloon-based experiments for the types of cosmic background radiation studies described in the SEU roadmap. Dr. Swordy noted that balloon-based experiments have long played an important role in advancing readiness of new technologies to the levels required for including the technology on a space flight mission. Balloon-based prototypes help in crossing the gap from technology readiness level 3 (TRL 3) to TRL 6. This led to a general discussion and consensus on the continuing role for balloon flights in maturing technologies for studying cosmic microwave background radiation, including the Planck Surveyor and the Energetic X-ray Imaging Survey Telescope (EXIST).

Dr. Swordy next described a suggestion from Dr. Peter Gorham for neutrino detection using the ice cap mass as a neutrino converter and a balloon-based detector to look for the UHF signal from the shower of particles emitted from neutrino conversion. If successful, this experiment would be first time neutrinos in this energy range from astrophysical objects have been detected. Useful characteristics of ultra-long duration balloons for astronomy and astrophysics include a science payload of 2,000 lb. However, balloon payloads for mission lifetimes greater than 100 days raise reliability issues for which current engineering resources are inadequate. Payload engineering costs are likely to increase by a factor of 10 or more. Other issues concern the existing infrastructure. For example the 30 kbps telemetry rate is low for the types of experiments Dr. Swordy described. Telemetry capabilities of at least 100 kbps would be more suitable. Flying in mid-latitudes could reduce atmospheric background for detecting charged particles. A question led to discussion of the use of ULDBs for observing in the infrared, for example to look at fine structure lines in atomic spectra. Other issues discussed were the feasibility and cost of pointing telescopes from balloons and the value of the Antarctic balloon experiment for neutrino observation, compared with experiments using the limb of the moon.

ULDB Program

Mr. Steve Smith of the Balloon Program Office, Wallops Flight Facility, Goddard Space Flight Center (GSFC), responded to the request made at the previous SEUS meeting for information on the baseline required for developing and sustaining ULDB capability. As a metric for the performance of the balloon program, he provided statistics on the percentage of NASA-related articles in *Science News* based on Balloon Program flights. Of the 83% of NASA-related articles on space science, 9 percent report on contributions from the Balloon Program. Since 1990, the trend in average hours per flight has been toward longer flight durations, with LDB flights continuing the trend to experiments requiring longer exposure times. As an example, the Trans-Iron Galactic Element Recorder (TIGER) mission flew for nearly 32 days by following a circumpolar trajectory around Antarctica from McMurdo Station. ULDB represents a new NASA science mission carrier. The 100-day flight durations would represent an order of magnitude increase over LDB duration. Internet accessibility to the package from the participating science institutions would be another significant addition. Stability of altitude during flight is another reason for moving from LDB to ULDB capability. The zero-pressure balloons used for LDB and shorter flights vary in altitude. An ultra-long distance balloon is a pressure vessel, maintaining a constant volume and density and therefore a constant float altitude. This stability allows flight durations to be extended to 100 days and longer.

The full-scale vehicle flight test in June 2002 showed that a prior problem with anomalous balloon shape during inflation had been fixed. A structural modification was made to force correct deployment of the balloon. The test suffered a premature failure due to a fabrication error. The fabricator missed two consecutive tendons in the structure, exceeding the design safety margins. The next test launch is planned for January 20, 2003. For both test flights, the suspended payload is 2,831 kg and the maximum flight altitude is 33.5 km. The total mass available for science detector and instrument support structure is 1,000 kg. The January test will incorporate a TDRSS high gain antenna added to the standard instrument package for LDB flights. Mr. Smith reviewed the power supply capabilities, telecommunications capability, command and data handling, mechanical structure, and attitude control for these test vehicles. Diagrams of the CREAM payload were used to illustrate the balloon support systems. The Balloon Program is setting aside a small amount of each year's budget for ULDB technology investment, but Mr. Smith believes a stronger technology investment program is needed to provide improvements. The potential improvements include higher altitude capability, trajectory control, longer duration, recovery capability, increased power and telecommunications, pointing control, and cost-effective cryogenic cooling. The need for trajectory control is driven by mitigation of safety risks when balloons fly over populated areas. Trajectory control would enable scientific observations to be made in mid-latitude, as well as payload recovery. The longer mission durations for ULDBs require more mission management than do LDB flights. Mr. Smith compared a baseline design-to-capability approach (design the science missions to fit the program technology) for a ULDB Program with an alternative design-to-requirements approach (design the program to support the science missions). Both models were used in the ULDB budgeting exercise that Mr. Smith presented to the SEUS. His final recommendations for consideration were a design-to-capacity baseline program costing about $25 million per year, with additional ULDB missions possible through the Explorer program. Key issues to be resolved if a ULDB program is to be implemented include the pending international agreement with Australia on balloon overflight and recovery, the renegotiation of the MOU with NSF, resolution on overflight safety restrictions for mid-latitude flights, and funding sufficient to maintain technical proficiency and to invest in technology for improved support capabilities.

A major topic of discussion was the methodology and models used for the flight safety determination and their appropriateness for balloon flights, as opposed to the rocket flights for which they were developed. Other topics discussed by the SEUS included potential interest of Earth and atmospheric scientists in smaller ULDBs and the ULDB interests of the Department of Defense and the new Department of Homeland Security. Another possibility is an extreme altitude ULDB, flying at just 1 mbar of atmospheric pressure, for which a 1,500-lb. suspended payload is technically feasible. This capability would provide new options for soft x-ray and ultraviolet (UV) astronomy.

Day 2 Morning Discussion

The SEUS discussed the background, current status, and future options for NSF-NASA cooperation on balloon flights as part of the U.S. Antarctic Program, in light of the presentations on the Polar Programs, the NASA Balloon Program, and ULDB science. Among the discussion topics were the constraints, stemming from the risk assessment model and methodology used by NASA, on balloon flight alternatives to Antarctic launches and recoveries. Past funding practice was discussed, and prospects for future funding alternatives were explored, including the prospects of NSF future funding to support the McMurdo Station. Given OSS budget constraints, acceptance by NASA of the infrastructure funding requested by NSF would probably require suspending balloon flights for several years after the flights in FY 2003. Several members expressed concern that the NSF position on funding of infrastructure required for Antarctic flights, although a relatively small element in both agencies' budgets, may bode ill for cooperation on larger ventures. With respect to ULDB prospects, members noted that the technology opens possibilities for more ambitious space science experiments than have been undertaken thus far. Successful pursuit of these opportunities over the long run will require a stable programmatic solution to the present difficulties. At the close of the discussion, the chair polled members on issues to discuss with the A&P Division Director and possibly to be included in a SEUS letter to the Space Science Advisory Committee (SScAC).

The SEUS discussed the NASA Exploration Team (NEXT) initiative, which had been briefed to the SEUS at its August 2002 meeting, and its relation to the A&P Working Group (A&PWG). With respect to the R&A Program, several members stressed that the work required to advance a technology from TRL 3 to TRL 6 typically goes beyond the capacity of an R&A budget. The members agreed with the chair's suggestion that the SEUS should emphasize the importance to OSS of implementing the second half of *Beyond Einstein*, which covers key technology development required for future SEU work. They also agreed with the chair's suggestion to express confidence in the A&P Working Group, rather than expressing an opinion on a particular approach to balancing the elements of the R&A Program. The recent report from the NAAAC and its implications for SEU programs was discussed. Dr. Swordy iterated the point, made during his presentation, that NASA needs avenues to attract young investigators through a mix of nearer-term, smaller scale projects, along with the major projects emphasized in *Beyond Einstein*.

International Gamma-ray Astrophysics Laboratory (INTEGRAL)
Dr. B. J. Teegarden from GSFC briefed the SEUS on the INTEGRAL mission, which was launched on a Proton rocket in October 2002 and is now in a two-month commissioning phase. Its basic science objective is gamma-ray astronomy in the range from 15 kev to 10 Mev, and INTEGRAL was conceived as a follow-on to the Compton Gamma-ray Observatory (GRO). The spacecraft weighs about 4 metric tons. The apogee of its 72-hour orbit is 130,000 km, while the perigee at 9,000 km just skims the proton radiation belt. The two main instruments are a spectrometer (SPI) with cooled germanium detectors and a gamma-ray imager with two layers of detection (IBIS). Supporting instruments provide monitoring in the optical and x-ray regions of the spectrum. SPI is a coded aperture telescope with 3° angular resolution and an 18° field of view. Its operating range is 20 to 8,000 kev. Primary background suppression is by active shielding. IBIS, which is also a coded aperture instrument, has 12 arc-minutes of resolution and a 9° x 9° field of view. The upper detector level in IBIS is a large array of CdTe detectors, which cover the gamma-ray energy range from 10 to 200 kev. The lower level consists of CsI detectors and covers the range from 200 kev to 10 Mev. The large arrays of small CdTe detectors (16,000 detectors) in IBIS provide significant improvement in angular resolution over GRO's capabilities. INTEGRAL capabilities are intermediate in energy range coverage between those of the Swift Gamma-ray Burst Explorer (Swift) and the Gamma-ray Large Area Space Telescope (GLAST). The three missions form a complementary set. NASA's contributions to INTEGRAL account for 3–5 percent of mission cost (total cost of approximately $600 million). These contributions include pulse shape discrimination electronics to provide background suppression for SPI, data analysis software for SPI, background modeling and analysis, pictures for IBIS, and part of the on-orbit tracking coverage (15 hours per orbit).

Dr. Teegarden said that initial results from calibration look good, although scientific data are embargoed until a press conference on December 18. Images from the two major instruments are in agreement and location of observed sources (e.g., CYG X3) has been consistent with other observations. Gamma-ray line spectroscopy of galactic aluminum-26 is one of the science objectives; INTEGRAL will provide a spectral resolution for aluminum-26 of 2.5 kev versus 200 kev for GRO. Although gamma-ray bursts were not an initial science objective, INTEGRAL instrumentation provides for prompt ground analysis of bursts (position of bursts on the order of 10 seconds). Thus, it can be used as a trigger for follow-up observations. The nominal observing phase for the mission is 2 years, with extension to a third year likely. The core program starts at 35 percent of the general program time and declines to 25 percent. The remainder of program time is for guest observers. Of the 113 guest observer proposals selected, 23 percent have U.S. principal investigators. Concerns about the mission include a problem with progressive degradation and loss of microstrips in the x-ray monitor. Thirty of the 528 microstrips (256 each in two identical detectors) have been lost so far. After the operating voltage was decreased, the loss rate decreased considerably, and one detector has been turned off to ensure capability over the mission life. The voltage decrease raised the threshold detection energy from 3 to 4.5 kev. The telemetry budget is being exceeded because the spectrometer's background counting rate is twice the pre-launch prediction. The concern that relates directly to NASA's role is poor quality of tracking by the NASA Goldstone station. More than half the passes have been unusable. The problem appears to be noise at the tracking station or in the link to the European primary station.

Astro-E2
Dr. Richard Kelley of GSFC, principal investigator for U.S. participation in the Astro-E2 joint mission with Japan, briefed the SEUS on preparations for this second attempt. (The original Astro-E mission suffered a launch failure in February 2000.) The science objective is to provide high spectral resolution over a broad x-ray range, particularly in the band for most of the astrophysically abundant elements. In July 2001, U.S. participation in Astro-E2 was approved as a NASA mission of opportunity. The observing method is non-dispersive spectroscopy, so extended observations can be made of extended sources such as clusters without degradation. Observations can be made across three orders of magnitude of bandwidth simultaneously. The three primary instruments are a hard x-ray detector system, an x-ray imaging spectrometer consisting of four x-ray CCD cameras arrayed around the base of the cooling Dewar, and an x-ray microcalorimeter. The Astro-E2 x-ray detectors provide a twofold improvement in energy resolution over the original design for Astro-E. The microcalorimeter represents the first time this technology has flown in space and provides the high-resolution nondispersive spectrometry capability. It measures the

energy of individual x-ray photons as heat and has a resolution of several electron volts in the 1 kev to 10 kev band. Its three-stage cooling system, which uses liquid helium as the third-stage coolant, has a design life of two years in orbit. Dr. Kelley illustrated some of the improvements in spectral resolution that should be achievable with the instrument improvements for Astro-E2. These improvements have significant implications for gathering information on galactic processes. In-flight calibration methods have also been improved. A pre-collimator system is being tested to eliminate off-axis background x-rays and increase sensitivity.

Foil production for the Astro-E2 mirrors is in progress, and Dr. Kelley expects production to be completed on schedule, with the first mirror scheduled to be shipped to Japan this winter. Assembly and calibration of the x-ray microcalorimeter will start in March 2003, with shipment to Japan in September 2003. The scheduled launch date for Astro-E2 is February 2005. Observing time will be divided between Japanese and U.S. projects, but all of the data will go into the U.S. archive after a year. SEUS members had questions about details of the imaging capabilities, the calibration techniques, and response time for repointing the observation axis.

SPIDR
Dr. Supriya Chakrabarti of Boston University provided an overview of the new SMEX mission named Spectroscopy and Photometry of Intergalactic Medium (IGM) Diffuse Radiation (SPIDR). The primary purpose of SPIDR is to look at the warm-hot phase of the IGM. It also provides opportunities to look at emissions within our galaxy. One science objective is to detect the cosmic web using oxygen VI emissions. SPIDR will also be able to look at the baryon inventory at different cosmic epochs and seek the missing 60 percent of baryons [that should exist according to current astrophysical theory]. The oxygen VI emissions will be used as a probe. Other science objectives include studying the high velocity clouds in the galactic halo, using oxygen VI and carbon IV emissions to diagnose halo characteristics. SPIDR will use imaging and spectroscopy for foreground light detection and discrimination. The scientific challenges include detecting weak signals within a high and varied background. The mission plan minimizes terrestrial background by use of a highly elliptical orbit. Corrections for the interplanetary background will be obtained by scheduling repeat observations at different times of the year. The instrumental design involves use of a single optical element, a toroidal diffraction grating. As the instrument rotates, a real signal (from a target source) will trace a sine curve in the Y dimension versus time. For Phase A, the project team built a prototype instrument to demonstrate that the weight requirement could be met. The science payload is being built at Boston University, the spacecraft hardware at Draper Laboratories. Massachusetts Institute of Technology is providing specialized engineering support. The funded mission duration is 3 years. The Phase B contract has been delayed by the delay in FY 2003 congressional appropriations.

The SEUS members and Dr. Chakrabarti discussed reconstruction of point sources via the observational technique versus discriminating features of larger sources and how this technique will be used to look at cosmic web features. In response to a question, Dr. Chakrabarti said the telemetry rate is several megabits per second, with two hours during each orbit for transmitting data. He reviewed the observation schedule for the 3-year mission duration.

Day 2 Afternoon Discussion
The next SEUS meeting is scheduled for Feb. 27–28, 2003, at Jet Propulsion Laboratory (JPL). The OS will also meet at JPL during that time, and the SScAC is meeting there the following week. The agenda for February will include review of the OSS strategic plan, presentations on SEU projects at JPL, a tour of SEU laboratories at JPL, updates on the Herschel and Planck missions, and a joint update with OS on SAFIR and SUVO. June was discussed as the approximate time for the subsequent SEUS meeting, with follow-up planning to continue by email.

Presentation of Issues with A&P Director
Dr. Anne Kinney, A&P Division Director, participated with the SEUS in a discussion of issues. Individual SEUS members initiated discussion of particular points in accordance with the division of topics made during the morning discussion. Dr. Simon Swordy led off by noting that the major projects presented in the *Beyond Einstein* roadmap for SEU are important, but the Division also needs a range of projects with varying size and time scales. The increase in the SMEX mission cap will help to maintain the vitality of the

Explorer program, he said, but the SEUS is concerned about the implication for a decrease in mission rate. Dr. Swordy also stressed the value of stimulating the interest of undergraduate and graduate physics students in space science through projects in which they can participate. Dr. Kinney acknowledged the important role that the Balloon Program plays both in doing science and in providing avenues for student involvement.

Dr. Sterl Phinney said that the SEUS has confidence in the approach being taken by the APWG to balance the R&A Program. On the issue of moving new technology across the gap from TRL 3 to TRL 6, the New Millennium Program provides some help but is limited in size. He encouraged attention to the sections of the *Beyond Einstein* roadmap that outline needed technology development. Dr. Phinney also asked Dr. Kinney about the process she and others in OSS will use in responding to results from the NEXT initiative. Dr. Kinney replied that the purpose of NEXT is to look at future uses for the International Space Station (ISS) and what science could be done in that context. The members expressed the concern of the science community about tying space science too closely to one technology approach. They discussed with Dr. Kinney the roles that SEUS might play in providing input on future science requirements.

Dr. Timothy Heckman asked about the process OSS will use in responding to the NAAAC recommendation on the Large-aperture Synoptic Survey Telescope (LSST). Dr. Kinney expressed interest in ways that the LSST project could be used to improve NASA-NSF interactions. One difficulty is that any additional NASA funding for LSST would come out of other SEU projects. Dr. Jacqueline Hewitt suggested that the difference in management styles between the two agencies may make it easier to collaborate on a programmatic level than on individual projects. An approach where the agencies decided on strategic division of project areas might help in meeting Administration goals for cross-agency coordination. Dr. Phinney remarked that the recommendation in the NAAAC report for $5 million additional funding for modeling in gravitation wave physics would be valuable to the NSF LIGO project initially but would be relevant to the NASA LISA mission later on. Dr. Heckman added that cooperation on the National Virtual Observatory (NVO), although a small area, could lead to improved cooperation on bigger efforts. Dr. Charles Dermer said that there were different views within SEUS on the relative merits of taking issue with the NSF position on support for the Antarctic balloon flights.

The discussion turned to ways and means to disseminate and build support for the *Beyond Einstein* roadmap, including SEUS's commitment to aid with that effort. Dr. Kinney agreed that it would be important to build support within the Administration for the roadmap. The Chair adjourned the meeting at 3:12 p.m.

AGENDA

Structure and Evolution of the Universe Subcommittee (SEUS)

December 3–4, 2002
NASA Headquarters

December 3 (Room 9H40 [PRC])

8:30 a.m.	R. Kolb	Welcome and Agenda
8:45 a.m.	Break (move to joint session with OS in room 6H46)	

Joint with OS (Room 6H46 [MIC-6])

9:00 a.m.	A. Kinney	Director's Report
9:45 a.m.	R. Kolb	SEU Roadmap Update
10:00 a.m.	A. Dressler	Origins Roadmap Update
10:15 a.m.	Break	
10:30 a.m.	M. Allen	OSS Strategic Planning Workshop Update
11:00 a.m.	D. Richstone	Astronomy & Physics Working Group Report
11:15 a.m.	J. Bregman	Space Archives Working Group Report
11:30 a.m.	B. Peterson/A. Saha	NAAAC Report
Noon	Lunch	
1:00 p.m.	L. Rafferty	Ethics Briefing
2:00 p.m.	Break (move back to room 9H40)	

SEUS Only (Room 9H40 [PRC])

2:30 p.m.	P. Looney	Discussion with OSTP
3:15 p.m.	All	Next Steps for Beyond Einstein
4:00 p.m.	D. Peacock/V. Jones	NSF/NASA Polar Programs
5:00 p.m.	Adjourn	

6:30 p.m. Committee Dinner (Le Rivage, 1000 Water Street SW [9th St & Maine Ave])

December 4 (Room 9H40 [PRC])

8:30 a.m.	All	Discussion
9:00 a.m.	S. Swordy	ULDB Science
9:30 a.m.	S. Smith	ULDB Program
10:30 a.m.	Break	
11:00 a.m.	P. Hertz	Explorer Program
11:30 a.m.	M. Salamon	R&A Program
Noon	Lunch	
	B. Teegarden	INTEGRAL (Lunch Talk)
1:00 p.m.	R. Kelley	Astro-E2
1:45 p.m.	S. Chakrabarti	SPIDR
2:30 p.m.	All	Discussion of Issues
3:00 p.m.	R. Kolb	Presentation of Issues with A&P Director
4:00 p.m.	Adjourn	

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STRUCTURE AND EVOLUTION OF THE UNIVERSE SUBCOMMITTEE (SEUS)
December 3–4, 2002
NASA Headquarters
Washington, DC

MEETING ATTENDEES

Subcommittee Members:

Kolb, Edward "Rocky" *(Chair)*	CERN
Bregman, Joel	University of Michigan
Cominsky, Lynn	Sonoma State University
Dermer, Charles	Naval Research Laboratory
Flanagan, Kathryn	Massachusetts Institute of Technology
Heckman, Timothy	Johns Hopkins University
Hertz, Paul *(Executive Secretary)*	NASA Headquarters
Hewitt, Jacqueline	Massachusetts Institute of Technology
Phinney, E. Sterl	California Institute of Technology
Swordy, Simon	University of Chicago
Wright, Edward	University of California, Los Angeles
Yorke, Harold	NASA/JPL

NASA Attendees:

Brass, Kent	NASA Headquarters
Christian, Eric	NASA Headquarters
Crane, Philippe	NASA Headquarters
DeMinco, Paul	NASA/GSFC
Hasan, Hashima	NASA Headquarters
Hayes, Jeffrey	NASA Headquarters
Horowitz, Steven	NASA Headquarters
Jones, W. Vernon	NASA Headquarters
Kelley, Richard	NASA/GSFC
Kinney, Anne	NASA Headquarters
Macklow, Glenn	NASA Headquarters
May, Lisa	NASA Headquarters
Moore, Mike	NASA Headquarters
Norris, Marian	NASA Headquarters
Purdy, Craig	NASA/GSFC
Salamon, Michael	NASA Headquarters
Schwartz, P. Chris	NASA/GSFC
Smith, J. Steve	NASA/GSFC
Sorrels, Carrie	NASA Headquarters
Teegarden, Bonnard	NASA/GSFC
White, Nicholas E.	NASA Headquarters

Other Attendees:

Beres, Kathleen	Orbital Corporation
Buchan, Mark	California Institute of Technology
Chakrabarti, Supriya	Boston University
Herman, Dan	Brashear LP
Lillie, Chuck	TRW
Looney, Patrick	Office of Science and Technology Policy

Malay, Jon	Ball Aerospace
Mundy, Lee	University of Maryland
Panicunin, Vernon	National Science Foundation
Peacock, David	National Science Foundation
Reese, Terry	no affiliation
Reichhardt, Tony	Nature Magazine
Turner, Kathy	Department of Energy

STRUCTURE AND EVOLUTION OF THE UNIVERSE SUBCOMMITTEE (SEUS)
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LIST OF PRESENTATION MATERIAL[1]

1) NASA-NSF Polar Programs (Jones)
2) Explorer Program Update to SEUS (Hertz)
3) Ultra-Long Duration Ballooning (Smith)
4) R&A Update and Issues (Salamon, via Hertz)
5) Appendix E.11, Technology Readiness Levels. From *Space Science Enterprise Management Handbook* (Salamon, via Hertz)

[1] Presentation and other materials distributed at the meeting are on file at NASA Headquarters, Code S, Washington, DC 20546.